82/117

How and Where to Use HYDRAULIC TRACERS

By GILBERT C. CLOSE
Field Editor

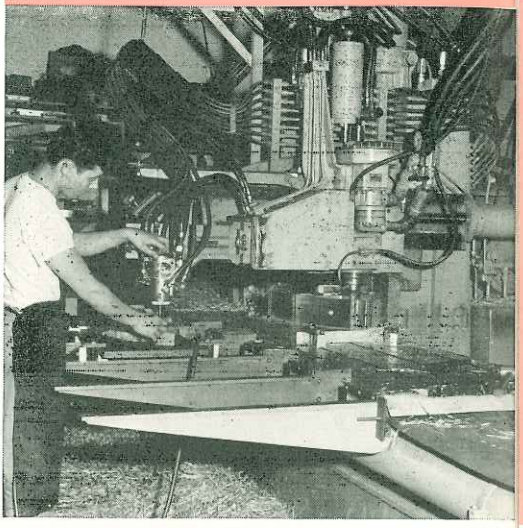
Reprinted from September 1957 Issue MODERN MACHINE SHOP

82/117

How and Where to Use HYDRAULIC TRACERS

The increasing trend toward designing of parts for tracer production has prompted this discussion.

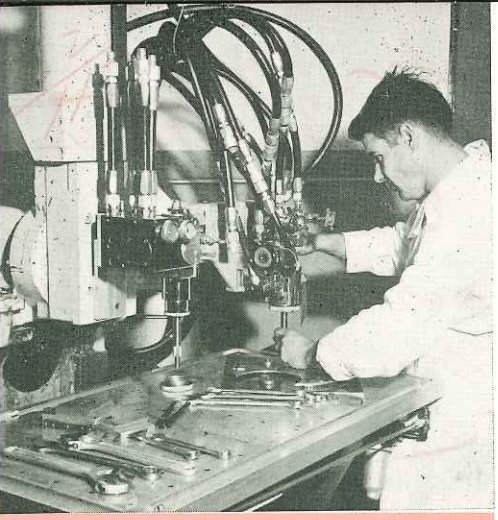
By GILBERT C. CLOSE
Field Editor



As a rule, machine shop tooling improvements are made to increase production, improve product quality, or both. While such improvements are economically advantageous, they are not absolutely necessary. Production could continue without them. The new tools merely do the required work faster and better.

Shop tooling improvements consisting of hydraulic tracer equipment do not necessarily fall in this category. While hydraulic tracer equipment has repeatedly proved its ability to speed production and improve quality on general production work, most hydraulic tracers are installed for the very fundamental reason that the shop is faced with work it cannot accomplish on a production basis without tracer equipment. In such cases, choice, or the desire to install new tooling, is not a factor. Shop management is faced with two alternatives—either install tracing equipment, or forego bidding on many of the contracts which are passed around by the nation's defense industry.

This situation has developed simply because engineers in many facets of the defense industry, especially in aircraft and missile production, are designing parts for tracer production. Their attitude toward the machine shop has become literally: "Here is the shape we want—you produce it." These engineers think nothing of including angles, curves, concave cuts and complex surfaces which, prior to the tracer,



(Above) Operator is applying final tests and adjustments to new 360-degree tracer under actual production conditions. Each new tracer is individually checked and adjusted.

(Left) This 8-foot Cleveland open-sided planer, which is equipped with a 360-degree hydraulic tracer, as well as a 180-degree tracer for depth control is used for the tracer-production of various types of critical metal structural components for different aircraft.

would have been next to impossible to produce by machining.

As this writer became more aware that the above described situation was developing, and that the trend toward designing parts for tracer production was gathering momentum, a decision was reached to seek out a source of reliable hydraulic tracer information and present a definitive discussion of the subject to readers of *Modern Machine Shop*. The source of information selected was True-Trace Corporation, El Monte, California. True-Trace Corporation was the west coast pioneer in the design, development and production of hydraulic tracing equipment. Two engineers still with the company, Roy Rosebrook and Henry Rombeck, developed the company's first precision hydraulic tracing valve and related equipment more than five years ago. Since that time, True-Trace has become one of the nation's major producers of hydraulic tracing equipment.

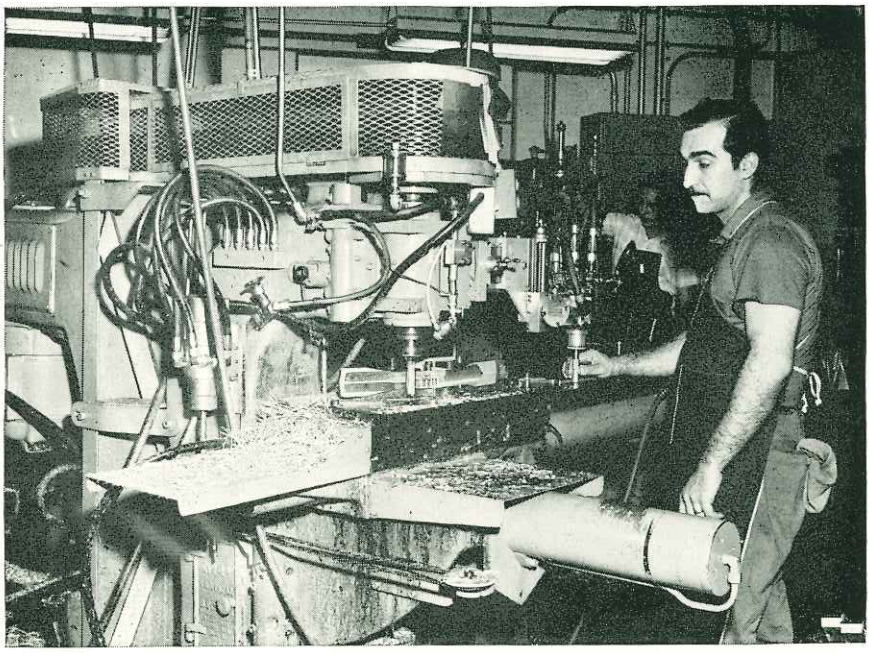
To supplement this experience, the company operates a large conversion shop where numerous machines are converted for tracing work. The True-Trace engineers and field men not only provided a great deal of information from their own background, but referred the writer to many outside tracer installations where other data could be obtained. This data should be a value to the numerous shop owners and operators who are now contemplating installation of tracer equipment, or who will be forced to contemplate such a move as the trend toward designing for tracer production continues to gather considerable momentum.

Before going any farther, it is time to point out that installation of tracer equipment does not imply the necessity of purchasing new, tracer-equipped machines. While these are available, in hundreds of cases on record, machines already available in the shop have been converted for tracer production. In

". . . any shop with an old mill, planer or lathe is equipped with basic tool for a tracer conversion job."

many cases, these were very old machines, some of them even unused at the time. Of course, during conversion, these old machines are modernized insofar as possible, and replacement parts are installed to restore the required precision. When converting a machine, it is also possible to custom build the conversion for specific types of specialized tracer production. Consequently, any shop with an old mill, planer, or lathe in storage, or one on the floor that can be spared, is equipped with the basic tool required for a tracer conversion job.

One, two, and three-dimensional hydraulic tracers are available, each operated by a single tracing stylus. The one-dimensional tracers are often mounted on a lathe for turning offsets (an integral cam on a shaft is a good example) during turning work, or are used in conjunction with a second tracer as will be explained later. The two-dimensional tracers are standard for two-dimensional con-



View showing a multiple tracer installation on a No. 4 Becker vertical mill. This installation utilizes a 360-degree tracer, as well as a 180-degree tracer for depth control purposes.

". . . three-dimensional tracers can duplicate any part against which the stylus can be moved for tracing."

touring work from billet or heavy sheet or plate stock. The three-dimensional tracers are operable through 360 degrees horizontally and 180 degrees vertically and can duplicate any part against which the stylus can be moved for tracing. With these three-dimensional tracers, a perfect hemisphere could be duplicated by using one setup or a perfect sphere by using two setups to complete the job.

In operation, when the tracer stylus moves along a control axis, it actuates a servo valve which feeds hydraulic fluid into a control cylinder, which in turn causes machine movements along the same axis. When a two-dimensional tracer is being used and stylus movement occurs in any direction in one plane, the stylus actuates two servo valves to feed fluid into two control cylinders which move the machine along two axes that correlate into the direction of stylus movement. The three-dimensional tracer stylus can move any direction and actuates

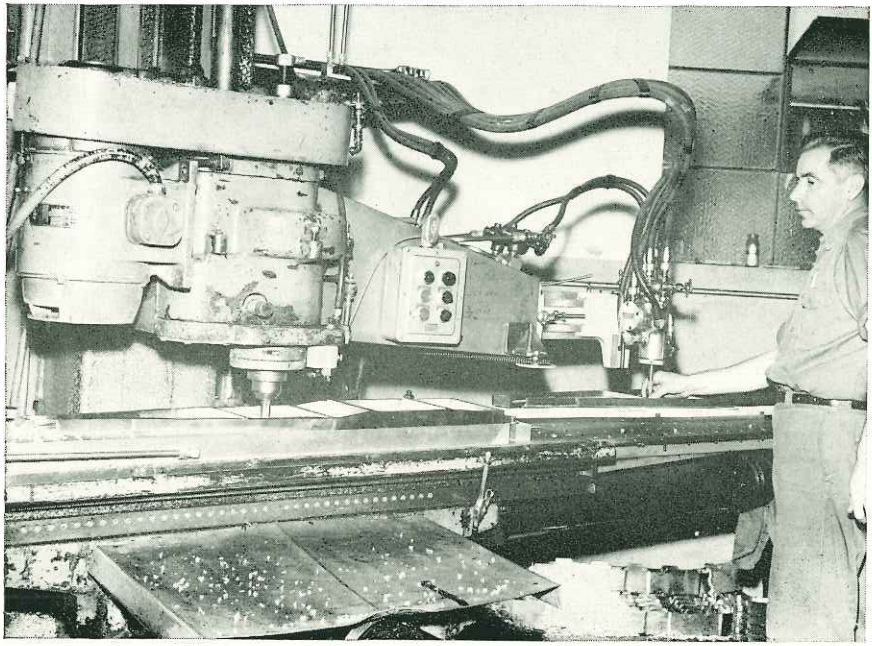


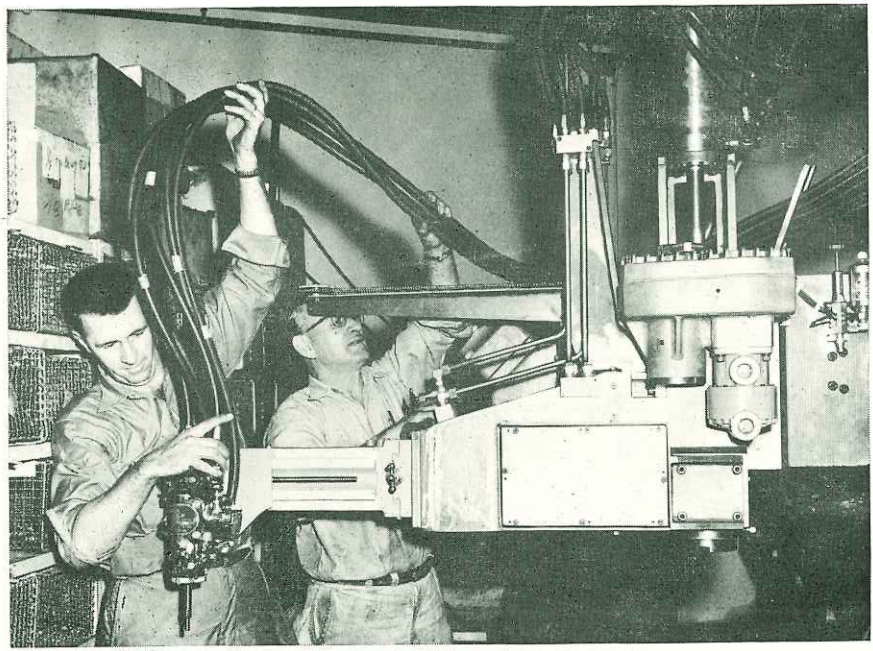
Illustration showing Pratt & Whitney jig borer equipped with a 360-degree tracer being used for tracing out a critical airplane wing component from a piece of solid billet stock.

"Tracer-equipped machines may be equipped with more than one hydraulic tracer assembly."

three servo valves to correlate the traverse, transverse, and vertical machine movements into the direction of stylus movement.

Tracer-equipped machines for special types of work may be equipped with more than one hydraulic tracer assembly. Vertical machine movements, for instance, may be obtained from a one-dimensional tracer located at some distance from a two-dimensional tracer which controls movements along the traverse and transverse axes. In a custom-built job for specialized work, a combination of a one-dimensional and three-dimensional, or two two-dimensional tracers, might be used, with the fourth valve triggering a rotary or tilting machine movement. The imagination alone limits multiple tracer valve applications along this line.

In one such multiple tracer installation, two hydraulic tracers were installed on a Pease planer with a 6-foot by 30-inch table and 31 inches between the columns. A



A hydraulic tracer is shown being installed on an open-sided planer during conversion. Many old shop machine tools are frequently rebuilt to allow for tracer production.

two-dimensional tracer controls the longitudinal movements of the table and the feed of the milling head on the cross rail. The tracer itself moves on the cross rail with the milling head, but the table moves longitudinally under the tracer and milling head. Another one-dimensional tracer controls the flow of hydraulic fluid to and from a third cylinder mounted with its axis perpendicular to the plane of the table and thus controls the depth of cut so that a constant floor level can be maintained. The converted planer can remove 75ST aluminum at the rate of 3 cubic inches per minute per horsepower while maintaining a precision tolerance. Climb milling is employed.

A typical tracer-produced aircraft component. This part would be almost impossible to produce by conventional machining.

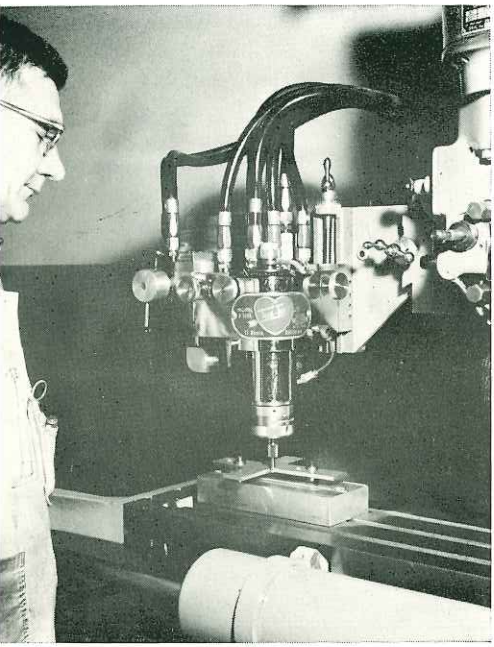
In most precision tracer work, a 1:1 size ratio is maintained between the tracer stylus and the cutting tool. Thus, in two-dimensional work, duplication is limited only by a concave radius smaller than the stylus and cutter. Convex radii or outside angles may be duplicated exactly. Square end mills are conventionally employed for two-dimensional cutting. Ball end mills are generally used in three-dimensional work where either concave or convex surfaces are involved. Correlating the point of contact of the tool with the work and the point of contact of the stylus with the pattern during setup is simplified by a micrometer adjustment on the tracer mounting bracket.

The patterns or templates used in tracer production do not conform to any specific standard. Usually, the pattern is made from the material most easily molded, cut, cast, or formed into the desired shape. Wood, plaster, or metal is commonly used. In two-dimensional work, a thin piece of sheet metal containing the proper two-dimensional contours will suffice. In many cases the master part is used. This is true especially in three-dimensional tracing. Of course, where only a small section of a very large part will be tracer-machined, such as a complicated flange on one end of an airplane spar cap, using the part itself as a pattern would be unwieldly. In this case, if a number of parts must be produced, a pattern or template of the section to be tracer-machined is indicated. Pattern hardness, rigidity (within minimum limits), or strength is not important as the operator uses only from five to

"The directional control advantage of the tracer can be applied in machining any material."

seven ounces of pressure in guiding the stylus of the tracer against the pattern.

It should be noted here that manipulation of the stylus, or any pressure used in guiding it, has no effect whatsoever on machine speeds. The very slight movement of the stylus in its ball-type mounting within the tracer valve body is completely absorbed by the servo valves as they move to admit more or less fluid into the control cylinders. The hydraulic tracer is purely a directional control device.

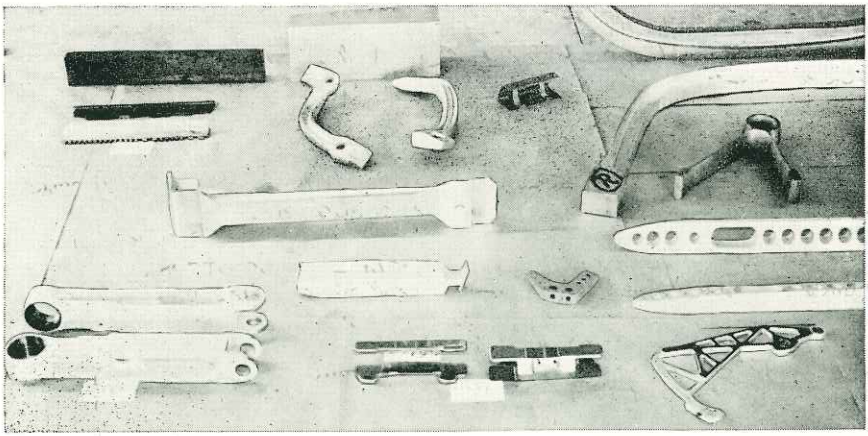


View showing a fully automatic tracer at work. The stylus traces the part without any aid whatsoever from the human hands.

The accuracy of tracer equipment in duplicating is partially dependent on the condition of the machine it is controlling, and any good machine with tracer equipment will duplicate to A.I.A. specifications. Consistency of duplication is another advantage. In one large aircraft plant tracer-machining a critical part, there were only four rejects in 22,000 parts caused by dimensional error. These four rejects can undoubtedly be attributed to the operator's hand faltering on the tracer stylus.

While the use of tracer-equipped machines is largely confined to the machining of aluminum at this time, this is only because the aircraft and missile production facilities were the first to employ tracer-equipped machines in large numbers. It will be obvious to any machinist that there is no connection between tracer control and the material being worked. The directional control advantages of the tracer, and its ability to resolve directions which involve two or three axes into the proper vector of machine movement, can be applied in machining any material.

One such conversion for tracer-machining a heat-treated 4340 steel forging was made on a Becker 4B vertical mill. The conversion employed a three-dimensional tracer, converting the mill into a high-speed duplicator that can be operat-



Typical tracer-produced parts. Design for tracer production is becoming a trend.

ed with semi-experienced help. Production tolerance on the conversion is held within 0.005 inch, but repetitive tolerances as close as 0.0005 inch are possible. The lead screws were replaced with tracer-controlled hydraulic cylinders in a manner to obtain the same relative motion of the table, saddle, and other moving parts.

Aside from production work, specialized uses for tracer equipment are being evolved as familiarity with this type of equipment increases. Many of the uses are based on the extreme accuracy of the hydraulic tracer in repetitive duplicating work. One large aircraft accessory plant, for instance, uses a tracer-equipped grinding machine for grinding the end mills that are used in machining titanium.

So far, this article may have given the impression that tracer machining is largely confined to parts specifically designed for tracer production. This is not true. In many cases, tracers have been installed on production line machines which continue to produce the same part after the conversion. The advantages are greater speed, better accuracy, and the substitution of relatively unskilled labor for the experienced machinists used prior to conversion. On one such production line in a major west coast airplant, production was increased better than four times by tracer conversion. Rejects due to dimensional error were sharply reduced. Now, relatively unskilled labor is used despite the improvements in speed, accuracy, and general quality.

While speaking of the "experience" required to operate a tracer-equipped production machine, this humorous incident should be mentioned. In one rather small shop, one of the tracer operators became ill for a few days. At the same time pickups and deliveries happened to fall off, and one of the truck drivers found himself with idle time on his hands. So the truck driver substituted for the absent tracer operator

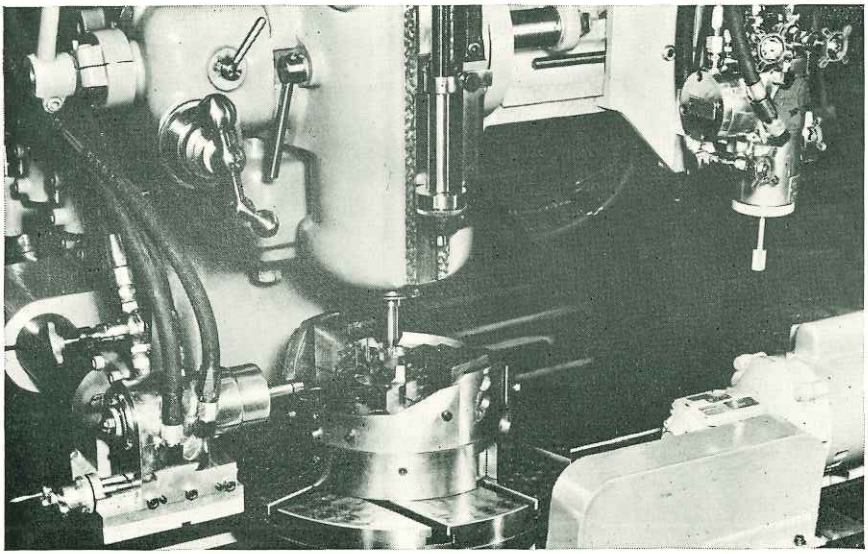
"When planning installation of tracer equipment, maximum requirements in directional control should be considered."

and produced entirely satisfactory work until the tracer operator returned to the job.

When planning installation of tracer equipment, either by purchasing it with a new machine or when converting an existing machine, maximum requirements in directional control should be considered. More than one tracer can be used to obtain additional control. One large Farnham spar mill in a west coast airplant employs seven separate tracers in its operation.

A final note before ending . . . Even as the author gathered data for this article, engineers at True-Trace Corporation revealed a new, completely automatic tracer now going into production. The stylus on this tracer follows the contours of the pattern or template independent of human touch. An illustration of this new automatic tracer in operation appears on page 108 of this article.

The advantages of automatic tracing are obvious. First, not even semi-skilled labor is required to operate it as the machine can be tooled so that it is completely automatic in operation after a blank part is clamped in place. Any conventional method of properly locating the blank in the machine can be used. Secondly, operator strain



Special cam milling operation being performed on a Gorton vertical mill equipped with a 360-degree tracer, plus a 180-degree tracer following cam on rotary table.

". . . operator strain and fatigue are reduced to the vanishing point and finishes are consistently good."

and fatigue are reduced to the vanishing point and finishes are consistently good. With conventional tracers, after long hours of work, the pulsations in the operator's hand as he guides the stylus may be reproduced on the part being machined. The automatic tracer will never "get tired." Finally, if a tracing job requires a justifiably long time to complete it, a single operator could operate more than one machine by making a setup in one machine while the other machines were tracing.

Engineering trends that prove advantageous in one industry will usually provide the same advantages in other fields. This seems true of the trend toward designing for tracer production. The leeway provided a design engineer to simplify, beautify, strengthen, and reduce the weight of a product when he can ignore shape limitations imposed by machining are obvious.

The concensus of opinion among shop operators now using and thereby familiar with tracer equipment is that the trend of designing for tracer production of machined parts is invading commercially competitive products, and that tracer-equipped machines have become a necessity wherever this type of work must be accomplished.

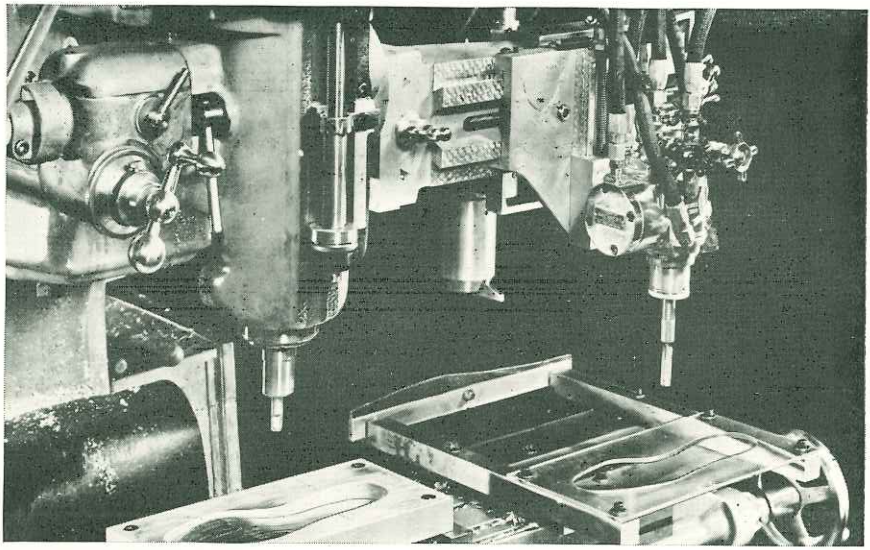


Illustration showing a Gorton 8 ½ D vertical type mill equipped with a 360-degree three-dimensional tracer for accurately producing a pattern from a simplified template setup.

Coordinate info is recorded on tape by flexowriter tape placed in console & magnetic machine control tape made — mfg. tape controls machine

TRUE-TRACE

SALES CORPORATION

9830 EAST RUSH STREET
EL MONTE, CALIFORNIA
Phone: CUmberland 3-4761

cable address: TRUETRACE

eastern offices
35 URBAN AVENUE
NEW CASSEL
LONG ISLAND, N. Y.

mid-western offices
2401 EATON LANE
RACINE
WISCONSIN